

CLAIMS

What is claimed is:

1. A method of fabricating a nanostructure array comprising:
 - providing a substrate having a top layer, and
 - depositing a sacrificial layer having a first etching characteristic,
 - patterning the sacrificial layer,
 - forming a thin conformal layer having a second etching characteristic over the patterned sacrificial structure,
wherein the first and second etching characteristics are different,
 - anisotropically etching the conformal layer to create a pattern,
 - removing the sacrificial layer,
 - transferring the resulting conformal layer structure to the substrate by etching, and
 - removing any remaining conformal layer structure,
 - thereby creating at least one nanostructure in the top layer.
2. The method of fabricating a nanostructure array of claim 1, further comprising:
 - reducing the dimension of the nanostructure.
3. The method of fabricating a nanostructure array of claim 2, wherein:
 - the reduction in dimension is accomplished by controlled etching or
 - converting to a material that has different etching characteristics and
 - removing the material.
4. The method of fabricating a nanostructure array of claim 3, wherein:

the nanostructure comprises Si, and

the reduction in dimension is accomplished by thermal oxidation to convert to SiO₂, and
contacting with an etchant to remove the oxide.

5. The method of fabricating a nanostructure array of claim 3, wherein:

the nanostructure comprises Si,

and the reduction in dimension is accomplished by controlled XeF₂ etch.

6. The method of fabricating a nanostructure array of claim 1, wherein:

the shape of at least one nanostructure is modified.

7. The method of fabricating a nanostructure array of claim 6, wherein:

at least part of the nanostructure is masked with resist, and

any unmasked part is removed by etching.

8. The method of fabricating a nanostructure array of claim 7, wherein:

the resist is photoresist,

and is patterned by photolithography.

9. The method of fabricating a nanostructure array of claim 7, wherein:

the resist is electron beam resist or ion beam resist,

and is patterned by electron beam lithography or ion beam lithography.

10. The method of fabricating a nanostructure array of claim 1, wherein:

the substrate is a multilayer structure, comprising:

a lower layer comprising silicon,

an intermediate layer comprising an insulating material,

an upper layer comprising a material chosen from the group consisting of semiconductors, metals and oxides, all of which may be doped or undoped.

11. The method of fabricating a nanostructure array of claim 10, wherein:
the insulating material is chosen from the group consisting of nitrides, oxides and polymers.
12. The method of fabricating a nanostructure array of claim 10, wherein:
the semiconductor is selected from the group consisting of group IV, III-V, II-VII semiconductors and semiconducting oxides, and it may be doped or undoped.
13. The method of fabricating a nanostructure array of claim 1, further comprising:
providing a protective layer below the sacrificial layer.
14. The method of fabricating a nanostructure array of claim 1, wherein:
 patterning the sacrificial layer is done by photolithography, electron beam lithography or ion beam lithography.
15. The method of fabricating a nanostructure array of claim 1, wherein:
the conformal layer comprises silicon oxide, silicon nitride and polysilicon.
16. The method of fabricating a nanostructure array of claim 1, wherein:
the conformal layer can be formed by chemical vapor deposition, spin coating, sputtering, evaporation or chemical reaction with the sacrificial layer.

17. The method of fabricating a nanostructure array of claim 1, wherein:
the sacrificial layer is removed by either plasma or wet etching.
18. The method of fabricating a nanostructure array of claim 1, further
comprising:
5 forming a contact in intimate contact with at least one nanostructure.
19. The method of fabricating a nanostructure array of claim 18, wherein:
the contact is formed by lithography.
20. The method of fabricating a nanostructure array of claim 19, wherein:
the lithography is photolithography.
- 10 21. The method of fabricating a nanostructure array of claim 18, wherein:
the contact is formed by forming a conducting film,
masking the contact area by lithography, and
etching any exposed film away.
22. The method of fabricating a nanostructure array of claim 1, wherein:
15 the substrate and the top layer comprise the same material, and
are separated by an insulator layer.
23. The method of fabricating a nanostructure array of claim 1, wherein:
the top layer comprises Si.
24. The method of fabricating a nanostructure array of claim 1, wherein:
20 at least one nanostructure is fabricated on a predetermined location with
positional control.
25. The method of fabricating a nanostructure array of claim 1, wherein:
there are between 1000 and 1 billion nanostructures on the array, and

are fabricated on a predetermined location and with positional control.

26. The method of fabricating a nanostructure array of claim 1, further comprising:
 - functionalizing at least one nanostructure with a functionalizing agent.
27. The method of fabricating a nanostructure array of claim 1, further comprising:
 - functionalizing more than one nanostructure with a functionalizing agent.
28. The method of fabricating a nanostructure array of claim 27, wherein:
 - the functionalizing agent is not the same for each nanostucture.
29. The method of fabricating a nanostructure array of claim 27, wherein more than one nanostructure is functionalized with one or more receptors selected from the group consisting of ss-DNAs, proteins, antibodies, platinum, photoactive molecules, photonic nanoparticle, inorganic ion, inorganic nanoparticle, magnetic ion, magnetic nanoparticle, electronic nanoparticle, metallic nanoparticle, metal oxide nanoparticle, gold nanoparticle, gold-coated nanoparticle, carbon nanotube, nanocrystal, quantum dot, protein domain, enzyme, hapten, antigen, biotin, digoxxygenin, lectin, toxin, radioactive label, fluorophore, chromophore, or a chemiluminescent molecule.
30. The method of fabricating a nanostructure array of claim 1, wherein:
 - the nanostructure comprises the top layer of the substrate.
31. The method of fabricating a nanostructure array of claim 1, further comprising:

at least one contact positioned on a top layer of the substrate, and the contact, the nanostructure and the top layer comprise the same material.

32. The method of fabricating a nanostructure array of claim 31, wherein:

5 there are a plurality of nanostructures, and

at least one contact is positioned in intimate contact with more than one nanostructure.

33. The method of fabricating a nanostructure array of claim 1, wherein:

the nanostructure comprises a material selected from the group consisting of SnO₂, TiO₂, Fe oxides, ZnO, WO₃, Ga₂O₃ and perovskites.

10 34. A method of fabricating a nanostructure array comprising at least one nanostructure positioned in a predetermined location, said method comprising:

15 providing a substrate having a sacrificial layer having a first etching characteristic,

patterning the sacrificial layer.

20 35. The method of fabricating a nanostructure array of claim 34, further comprising:

reducing the dimension of the nanostructure.

36. The method of fabricating a nanostructure array of claim 35, wherein:

the reduction in dimension is accomplished by controlled etching or converting to a material that has different etching characteristics and removing the material.

37. The method of fabricating a nanostructure array of claim 36, wherein:

5 the nanostructure comprises Si, and

the reduction in dimension is accomplished by thermal oxidation to convert to SiO_2 , and

contacting with an etchant to remove the oxide.

38. The method of fabricating a nanostructure array of claim 36, wherein:

10 the nanostructure comprises Si,

and the reduction in dimension is accomplished by controlled XeF_2 etch.

39. The method of fabricating a nanostructure array of claim 34, wherein:

the shape of at least one nanostructure is modified.

40. The method of fabricating a nanostructure array of claim 39, wherein:

.5 at least part of the nanostructure is masked with resist, and

any unmasked part is removed by etching.

41. The method of fabricating a nanostructure array of claim 40, wherein:

the resist is photoresist,

and is patterned by photolithography.

42. The method of fabricating a nanostructure array of claim 40, wherein:

the resist is electron beam resist or ion beam resist,

and is patterned by electron beam lithography or ion beam lithography.

43. The method of fabricating a nanostructure array of claim 34, wherein:

the substrate is a multilayer structure, comprising:
a lower layer comprising silicon,
an intermediate layer comprising an insulating material,
an upper layer comprising a material chosen from the group consisting of
semiconductors, metals and oxides, all of which may be doped or
undoped.

5 44. The method of fabricating a nanostructure array of claim 43, wherein:

the insulating material is chosen from the group consisting of nitrides,
oxides and polymers.

.0 45. The method of fabricating a nanostructure array of claim 43, wherein:

the semiconductor is selected from the group consisting of group IV, III-V, II-VI semiconductors and semiconducting oxides, and it may be doped
or undoped.

46. The method of fabricating a nanostructure array of claim 34, further

5 comprising:

providing a protective layer below the sacrificial layer.

47. The method of fabricating a nanostructure array of claim 34, wherein:

patterning the sacrificial layer is done by photolithography, electron
beam lithography or ion beam lithography.

.0 48. The method of fabricating a nanostructure array of claim 34, wherein:

the is a conformal layer, and

the conformal layer comprises silicon oxide, silicon nitride and
polysilicon.

49. The method of fabricating a nanostructure array of claim 48, wherein:

the conformal layer can be formed by chemical vapor deposition, spin coating, sputtering, evaporation or chemical reaction with the sacrificial layer.

50. The method of fabricating a nanostructure array of claim 1, wherein:

the sacrificial layer is removed by either plasma or wet etching.

51. The method of fabricating a nanostructure array of claim 34, further comprising:

forming a contact in intimate contact with at least one nanostructure.

52. The method of fabricating a nanostructure array of claim 51, wherein:

the contact is formed by lithography.

53. The method of fabricating a nanostructure array of claim 52, wherein:

the Lithography is photolithography.

54. The method of fabricating a nanostructure array of claim 51, wherein:

the contact is formed by forming a conducting film,
masking the contact area by lithography, and
etching any exposed film away.

55. The method of fabricating a nanostructure array of claim 34, wherein:

the substrate and the top layer comprise the same material, and
are separated by an insulator layer.

56. The method of fabricating a nanostructure array of claim 34, wherein:

the top layer comprises Si.

57. The method of fabricating a nanostructure array of claim 34, wherein:

at least one nanostructure is fabricated on a predetermined location with positional control.

58. The method of fabricating a nanostructure array of claim 34, wherein:

there are between 1000 and 1 billion nanostructures on the array, and
are fabricated on a predetermined location and with positional control.

5 59. The method of fabricating a nanostructure array of claim 34, further comprising:

functionalizing at least one nanostructure with a functionalizing agent.

60. The method of fabricating a nanostructure array of claim 34, further comprising:

functionalizing more than one nanostructure with a functionalizing agent.

61. The method of fabricating a nanostructure array of claim 60, wherein:
the functionalizing agent is not the same for each nanostucture.

62. The method of fabricating a nanostructure array of claim 60, wherein more
than one nanostructure is functionalized with one or more receptors
selected from the group consisting of ss-DNAs, proteins, antibodies,
platinum, photoactive molecules, photonic nanoparticle, inorganic ion,
inorganic nanoparticle, magnetic ion, magnetic nanoparticle, electronic
nanoparticle, metallic nanoparticle, metal oxide nanoparticle, gold
nanoparticle, gold-coated nanoparticle, carbon nanotube, nanocrystal,
quantum dot, protein domain, enzyme, haptene, antigen, biotin,
digoxigenin, lectin, toxin, radioactive label, fluorophore, chromophore, or
a chemiluminescent molecule.

63. The method of fabricating a nanostructure array of claim 34, wherein:

the nanostructure comprises the top layer of the substrate.

64. The method of fabricating a nanostructure array of claim 34, further comprising:

5 at least one contact positioned on a top layer of the substrate, and
the contact, the nanostructure and the top layer comprise the same
material.

65. The method of fabricating a nanostructure array of claim 34, wherein:

there are a plurality of nanostructures, and

0 at least one contact is positioned in intimate contact with more than one
nanostructure.

66. The method of fabricating a nanostructure array of claim 34, wherein:

the nanostructure comprises a material selected from the group consisting
of SnO₂, TiO₂, Fe oxides, ZnO, WO₃, Ga₂O₃ and perovskites.

5

67. A method of fabricating a nanostructure array, comprising

providing a first substrate,

depositing a sacrificial layer having a first etching characteristic,

patterning the sacrificial layer,

0 depositing a thin conformal layer having a second etching characteristic over
the patterned sacrificial structure, wherein

the first and second etching characteristics are different,

anisotropically etching the conformal layer to create a pattern,

removing the sacrificial layer,
transferring the resulting conformal layer structure to the first substrate by
etching, and
removing any remaining conformal layer structure, thus creating
5 nanostructure array pattern on the first substrate,
contacting the nanostructure array pattern with a second substrate
containing a resist to create an impression pattern in the resist,
anisotropically transferring the pattern into entire resist, and
vertically depositing a desired composition onto the pattern and
10 removing the resist,
thereby creating at least one nanostructure on the second substrate.

68. The method of fabricating a nanostructure array of claim 67, further

comprising:

.5 reducing the dimension of the nanostructure.

69. The method of fabricating a nanostructure array of claim 68, wherein:

the reduction in dimension is accomplished by controlled etching or
converting to a material that has different etching characteristics and
removing the material.

.0 70. The method of fabricating a nanostructure array of claim 69, wherein:

the nanostructure comprises Si, and

the reduction in dimension is accomplished by thermal oxidation to
convert to SiO₂, and

contacting with an etchant to remove the oxide:

71. The method of fabricating a nanostructure array of claim 69, wherein:
 - the nanostructure comprises Si,
 - and the reduction in dimension is accomplished by controlled XeF₂ etch.
- 5 72. The method of fabricating a nanostructure array of claim 67, wherein:
 - the shape of at least one nanostructure is modified.
73. The method of fabricating a nanostructure array of claim 72, wherein:
 - at least part of the nanostructure is masked with resist, and
 - any unmasked part is removed by etching.
- .0 74. The method of fabricating a nanostructure array of claim 73, wherein:
 - the resist is photoresist,
 - and is patterned by photolithography.
75. The method of fabricating a nanostructure array of claim 73, wherein:
 - the resist is electron beam resist or ion beam resist,
 - and is patterned by electron beam lithography or ion beam lithography.
- 5 76. The method of fabricating a nanostructure array of claim 67, wherein:
 - the substrate is a multilayer structure, comprising:
 - a lower layer comprising silicon,
 - an intermediate layer comprising an insulating material,
 - an upper layer comprising a mateial chosen from the group consisting of semiconductors, metals and oxides, all of which may be doped or undoped.
- 0 77. The method of fabricating a nanostructure array of claim 76, wherein:

the insulating material is chosen from the group consisting of nitrides, oxides and polymers.

78. The method of fabricating a nanostructure array of claim 76, wherein:

the semiconductor is selected from the group consisting of group IV, III-V, II-VII semiconductors and semiconducting oxides, and it may be doped or undoped.

79. The method of fabricating a nanostructure array of claim 67, further comprising:

providing a protective layer below the sacrificial layer.

80. The method of fabricating a nanostructure array of claim 67, wherein:

patterning the sacrificial layer is done by photolithography, electron beam lithography or ion beam lithography.

81. The method of fabricating a nanostructure array of claim 67, wherein:
the conformal layer comprises silicon oxide, silicon nitride and
polysilicon.

82. The method of fabricating a nanostructure array of claim 67, wherein:
the conformal layer can be formed by chemical vapor deposition, spin coating, sputtering, evaporation or chemical reaction with the sacrificial layer.

83. The method of fabricating a nanostructure array of claim 67, wherein:
the sacrificial layer is removed by either plasma or wet etching.

84. The method of fabricating a nanostructure array of claim 67, further comprising:

forming a contact in intimate contact with at least one nanostructure.

85. The method of fabricating a nanostructure array of claim 84, wherein:

the contact is formed by lithography.

86. The method of fabricating a nanostructure array of claim 85, wherein:

the lithography is photolithography.

87. The method of fabricating a nanostructure array of claim 84, wherein:

the contact is formed by forming a conducting film,

masking the contact area by lithography, and

etching any exposed film away.

88. The method of fabricating a nanostructure array of claim 67, wherein:

the substrate and the top layer comprise the same material, and

are separated by an insulator layer.

89. The method of fabricating a nanostructure array of claim 67, wherein:

the top layer comprises Si.

90. The method of fabricating a nanostructure array of claim 67, wherein:

at least one nanostructure is fabricated on a predetermined location with

positional control.

91. The method of fabricating a nanostructure array of claim 67, wherein:

there are between 1000 and 1 billion nanostructures on the array, and

0 are fabricated on a predetermined location and with positional control.

92. The method of fabricating a nanostructure array of claim 67, further

comprising:

functionalizing at least one nanostructure with a functionalizing agent.

93. The method of fabricating a nanostructure array of claim 67, further comprising:

functionalizing more than one nanostructure with a functionalizing agent.

94. The method of fabricating a nanostructure array of claim 38, wherein:

the functionalizing agent is not the same for each nanostucture.

95. The method of fabricating a nanostructure array of claim 67, wherein more

than one nanostructure is functionalized with one or more receptors

selected from the group consisting of ss-DNAs, proteins, antibodies,

platinum, photoactive molecules, photonic nanoparticle, inorganic ion,

inorganic nanoparticle, magnetic ion, magnetic nanoparticle, electronic

nanoparticle, metallic nanoparticle, metal oxide nanoparticle, gold

nanoparticle, gold-coated nanoparticle, carbon nanotube, nanocrystal,

quantum dot, protein domain, enzyme, hapten, antigen, biotin,

digoxigenin, lectin, toxin, radioactive label, fluorophore, chromophore, or

a chemiluminescent molecule.

96. The method of fabricating a nanostructure array of claim 67, wherein:

the nanostructure comprises the top layer of the substrate.

97. The method of fabricating a nanostructure array of claim 67, further

comprising:

at least one contact positioned on a top layer of the substrate, and

the contact, the nanostructure and the top layer comprise the same

material.

98. The method of fabricating a nanostructure array of claim 67, wherein:

there are a plurality of nanostructures, and
at least one contact is positioned in intimate contact with more than one
nanostructure.

99. The method of fabricating a nanostructure array of claim 67, wherein:

5 the nanostructure comprises a material selected from the group consisting
of SnO₂, TiO₂, Fe oxides, ZnO, WO₃, Ga₂O₃ and perovskites.

100. A sensor device, comprising:

a substrate,
an insulating layer, and

10 at least one nanostructure overlying the insulating layer in a predetermined
position.

101. The sensor device of claim 100, further comprising:

5 at least one nanostructure is functionalized with a receptor selected from
the group consisting of ss-DNAs, proteins, antibodies, platinum,
photoactive molecules, photonic nanoparticle, inorganic ion, inorganic
nanoparticle, magnetic ion, magnetic nanoparticle, electronic nanoparticle,
metallic nanoparticle, metal oxide nanoparticle, gold nanoparticle,
gold-coated nanoparticle, carbon nanotube, nanocrystal, quantum dot,
protein domain, enzyme, hapten, antigen, biotin, digoxigenin, lectin,
10 toxin, radioactive label, fluorophore, chromophore, or chemiluminescent
molecule.

102. The sensor device of claim 100, wherein:

the substrate comprises silicon.

103. The sensor device of claim 100, wherein:

at least one nanostructure is suspended from the substrate.

104. The sensor device of claim 100, wherein:

the nanostructure has a shape comprising open ended and/or closed ended.

5 105. The sensor device of claim 100, wherein:

the substrate is a multilayer structure, comprising:

a lower layer comprising silicon,

an intermediate layer comprising an insulating material,

an upper layer comprising a mateial chosen from the group consisting of

10 semiconductors, metals and oxides, all of which may be doped or

undoped.

106. The sensor device of claim 105, wherein:

the insulating material is chosen from the group consisting of nitrides,

oxides and polymers.

.5 107. The sensor device of claim 106, wherein:

the semiconductor is selected from the group consisting of group IV, III-

V, II-VII semiconductors and semiconducting oxides, and it may be doped

or undoped.

108. The sensor device of claim 100, wherein:

0 the substrate comprises a top layer, and

the substrate and the top layer comprise the same material, and

are separated by an insulator layer.

109. The sensor device of claim 108, wherein:

the top layer comprises Si.

110. The sensor device of claim 100, wherein:

there are between 1000 and 1 billion nanostructures on the array.

111. The sensor device of claim 100, wherein:

the nanostructure is functionalized with at least one functionalizing agent

112. The sensor device of claim 100, wherein:

there are a plurality of nanostructures and more than one nanostructure is functionalized with at least one functionalizing agent.

113. The sensor device of claim 112, wherein:

the functionalizing agent is not the same for each nanostructure.

114. The sensor device of claim 100, wherein:

the nanostructure comprises a top layer of the substrate.

115. The sensor device of claim 100, further comprising:

at least one contact positioned on a top layer of the substrate, and
the contact, the nanostructure and the top layer comprise the same
material.

116. The sensor device of claim 100, wherein:

there are a plurality of nanostructures, and

at least one contact is positioned in intimate contact with more than one
nanostructure.

117. The sensor device of claim 100, wherein:

the nanostructure comprises a material selected from the group consisting
of SnO₂, TiO₂, Fe oxides, ZnO, WO₃, Ga₂O₃ and perovskites.

118. A nanostructure array, comprising:

a substrate,

an insulating layer, and

at least one nanostructure overlying the insulating layer in a predetermined position.

5

119. The nanostructure array of claim 118, further comprising:

at least one nanostructure is functionalized with a receptor selected from the group consisting of ss-DNAs, proteins, antibodies, platinum, photoactive molecules, photonic nanoparticle, inorganic ion, inorganic nanoparticle, magnetic ion, magnetic nanoparticle, electronic nanoparticle, metallic nanoparticle, metal oxide nanoparticle, gold nanoparticle, gold-coated nanoparticle, carbon nanotube, nanocrystal, quantum dot, protein domain, enzyme, hapten, antigen, biotin, digoxigenin, lectin, toxin, radioactive label, fluorophore, chromophore, or chemiluminescent molecule.

10

.5

120. The nanostructure array of claim 118, wherein:

the substrate comprises silicon.

121. The nanostructure array of claim 118, wherein:

at least one nanostructure is suspended from the substrate.

0

122. The nanostructure array of claim 118, wherein:

the nanostructure has a shape comprising open ended and/or closed ended.

123. The nanostructure array of claim 118, wherein:

the substrate is a multilayer structure, comprising:

a lower layer comprising silicon,
an intermediate layer comprising an insulating material,
an upper layer comprising a material chosen from the group consisting of
semiconductors, metals and oxides, all of which may be doped or
undoped.

5

124. The nanostructure array of claim 118, wherein:

the insulating material is chosen from the group consisting of nitrides,
oxides and polymers.

125. The nanostructure array of claim 123, wherein:

0 the semiconductor is selected from the group consisting of group IV, III-V,
V, II-VII semiconductors and semiconducting oxides, and it may be doped
or undoped.

126. The nanostructure array of claim 118, wherein:

5 the substrate comprises a top layer, and
the substrate and the top layer comprise the same material, and
are separated by an insulator layer.

127. The nanostructure array of claim 126, wherein:

the top layer comprises Si.

128. The nanostructure array of claim 118, wherein:

) there are between 1000 and 1 billion nanostructures on the array..

129. The nanostructure array of claim 118, wherein:

the nanostructure is functionalized with at least one functionalizing agent

130. The nanostructure array of claim 118, wherein:

there are a plurality of nanostructures and more than one nanostructure is functionalized with at least one functionalizing agent.

131. The nanostructure array of claim 130, wherein:

the functionalizing agent is not the same for each nanostructure.

5 132. The nanostructure array of claim 118, wherein:

the nanostructure comprises a top layer of the substrate.

133. The nanostructure array of claim 118, further comprising:

at least one contact positioned on a top layer of the substrate, and

10 the contact, the nanostructure and the top layer comprise the same material.

134. The nanostructure array of claim 118, wherein:

there are a plurality of nanostructures, and

at least one contact is positioned in intimate contact with more than one nanostructure.

5 135. The nanostructure array of claim 118, wherein:

the nanostructure comprises a material selected from the group consisting of SnO₂, TiO₂, Fe oxides, ZnO, WO₃, Ga₂O₃ and perovskites.